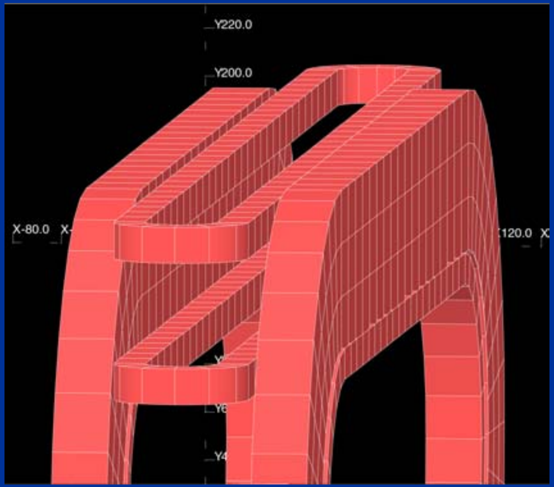
LBNL
Superconducting Magnet Program

Presentation to HEPAP

March 6, 2003

Stephen A. Gourlay

Superconducting Magnet Program



- Program Overview
  - Mission and Philosophy
  - History
  - Conductor and Materials
  - Magnets

- Technical Progress and Current Status

- Future Plans
  - Base Program
  - LHC Accelerator Research Program

Mission and Philosophy

- Accelerator Magnet Program emphasizing development of new technology for HEP
  - Issue-driven accelerator magnet program
  - Explore parameter space and challenge existing limits
    - High fields/gradients
    - Aperture
    - Field quality
    - Cost effective designs

"LBNL continues to lead the US effort (possibly the world effort) in advanced high-field superconducting magnet technology for high energy physics"

J. O'Fallon, Nov. 2001 Program Review

HEPAP Recommendations

- 2001
  - "... high priority to accelerator R&D because it is absolutely critical to the future of our field".
    - LBNL has been developing enabling technology for HEP for over 20 years
  - "High-field magnet research is particularly important"
    - LBNL has produced record breaking fields in two different geometries
    - No program has built more magnets with fields exceeding 10 Tesla
    - LBNL leadership of the LARP Magnet Program (S. Gourlay)
    - LBNL leadership of the DOE/HEP Conductor Development Program (R. Scanlan)
  - "efforts should be made to form an international collaboration as early as possible".
    - LBNL-sponsored international workshop on "Magnets beyond NbTi" (3/17-18/03)
    - Participation in ESGARD (European Steering Group on Accelerator R&D)

History of Program Contributions

NbTi Technology

- SSC
  - First 40 mm dipole prototypes
  - Quad prototypes (1m and 5m)
  - Materials and cable development
  - D19
    - **World Record Dipole field of 10.15 T**
    - **50 mm aperture SSC prototype**
- LHC
  - Cable for IR quads
  - IR quad design
  - DFBX components

Nb_3Sn Technology

- Cosθ geometry
  - D19h – Nb_3Sn/NbTi hybrid
  - D20
    - **World record dipole field of 13.5 T**
    - **50 mm aperture**
- Racetrack geometry
  - Common coil
    - **6 T, 12.2 T, 10 T**
    - **World record dipole field of 14.7 T**
  - "H" geometry
    - **> 15 T (This summer)**

Superconducting Magnet Program

Full spectrum development program for superconducting magnet technology

Materials and Conductor

Magnets

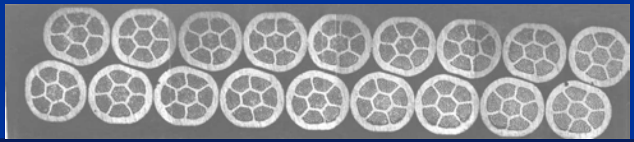
- Two decades (+) at the forefront of magnet technology
  - Our program maintains continuity
    - **Driven by HEP, not lab priorities**
  - Opportunity for innovation – not just an iteration of what was done before
- Strong interactions with industry, labs and universities
  - Exceptional record in materials development with industry
    - **DOE/HEP Conductor Development Program**
    - **SBIR's**
    - **Organizer and sponsor of Low Temperature Superconductor Workshop**

World experts in the application of Nb_3Sn technology to accelerator magnets

SC Materials and Cable Development

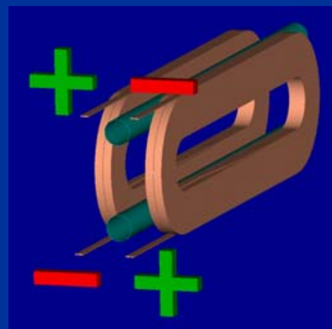
State of the art cabling facility to support HEP technology programs

- Lead Lab for DOE Conductor Development Program
  - Significant progress on Nb_3Sn J_C
    - 50% increase in 3 years
    - ~ 3,000 A/mm^2 at 12 T and 4.2 K
- LHC HGQ Cable
  - NbTi cable for FNAL completed 2-02
  - Fully keystoned Nb_3Sn for LHC upgrade
- Cable R&D
  - Explore the limits of Rutherford-type cables
    - New techniques
    - New Materials (HTS)
- Outside Support
  - FNAL, BNL, Texas A&M, U. Twente, SBIRs

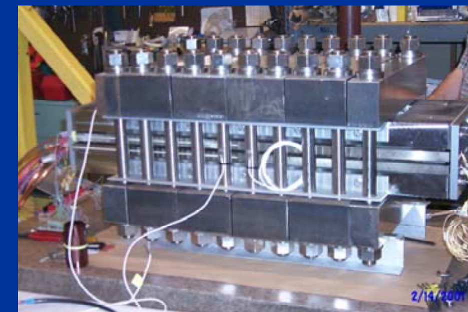


Common Coil Magnets at LBNL

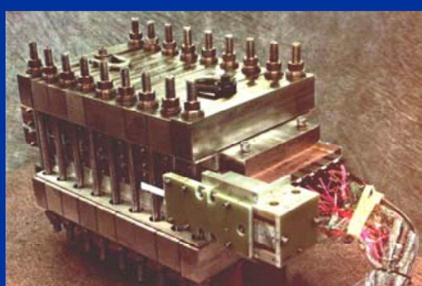
- **High Field**
- **Field Quality**
- **Simple Fabrication Techniques**



10.9 Tesla
RD3-c



12 Tesla
RT1



6 Tesla
RD2

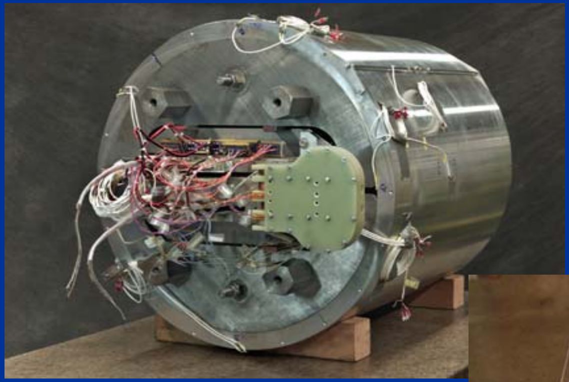
12 Tesla
SM-01

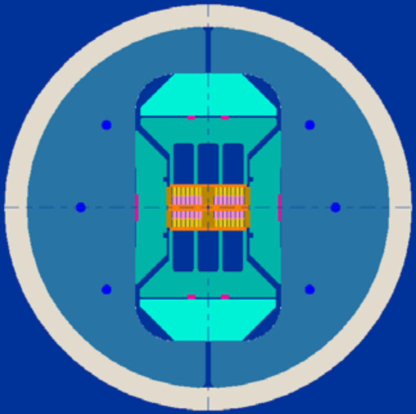
14.7 Tesla
RD3-b

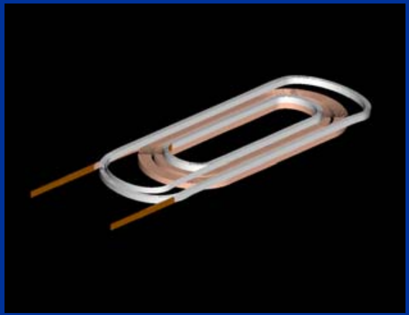
Magnet Development

Fully Integrated Program

- Field quality design options
  - RD Series
- New geometries for high field
  - HD-Series
- Technology Development
  - Sub-scale model program (SM)



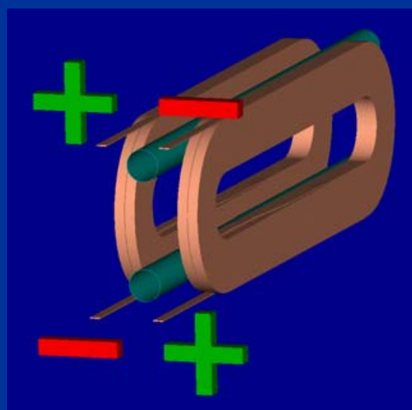




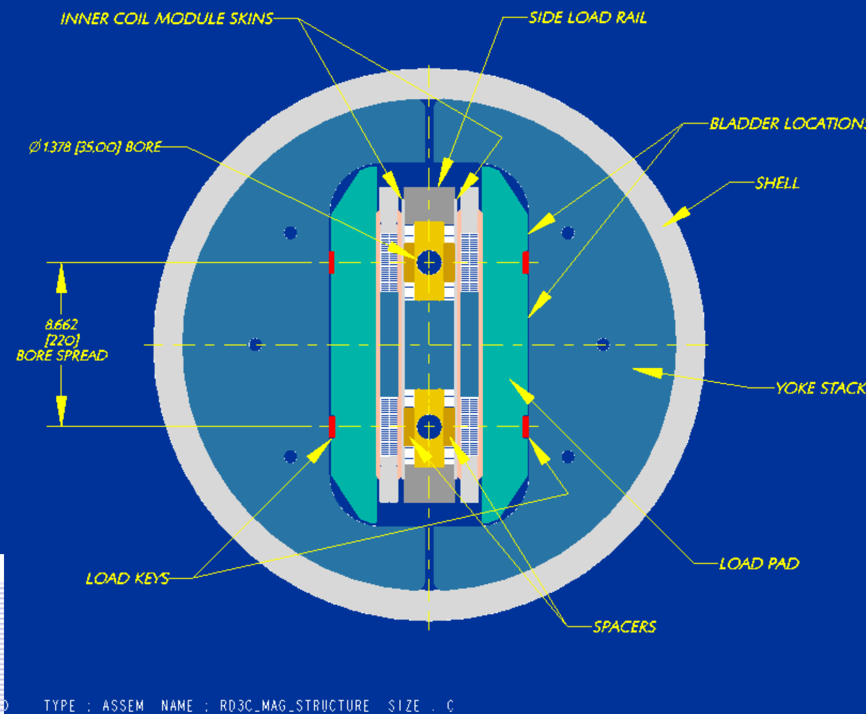
RD-Series

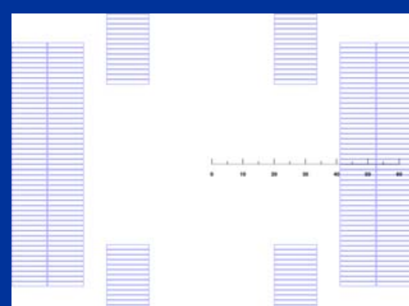
Explore potential for accelerator quality magnets

Common Coil geometry



Emphasis on field and field quality





Sub-Scale Magnet Series

Parallel Program for Technology Development

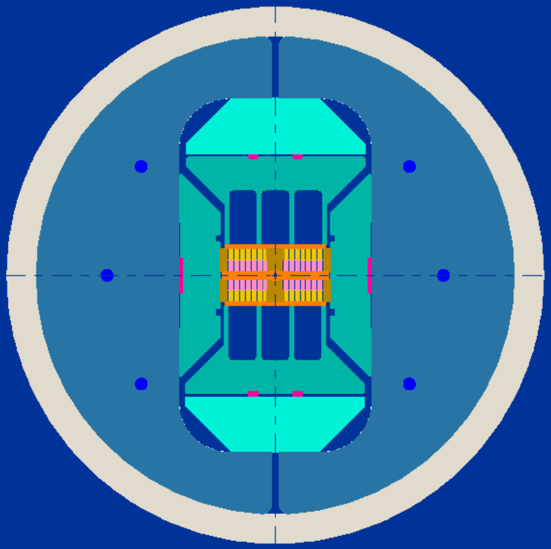
High Productivity - Anticipate a total of 5 tests this year

- Scaled version of full-size magnet
  - Approx. 1/3 scale
- Field range of 9 – 12 Tesla
- Simple two-layer racetrack coils
  - 5 kg of material per coil
- Streamlined test facility
  - Small dewar (no refrigerator)
  - Full crane coverage

HD-Series

Simple geometries to push the limits of conductor and materials

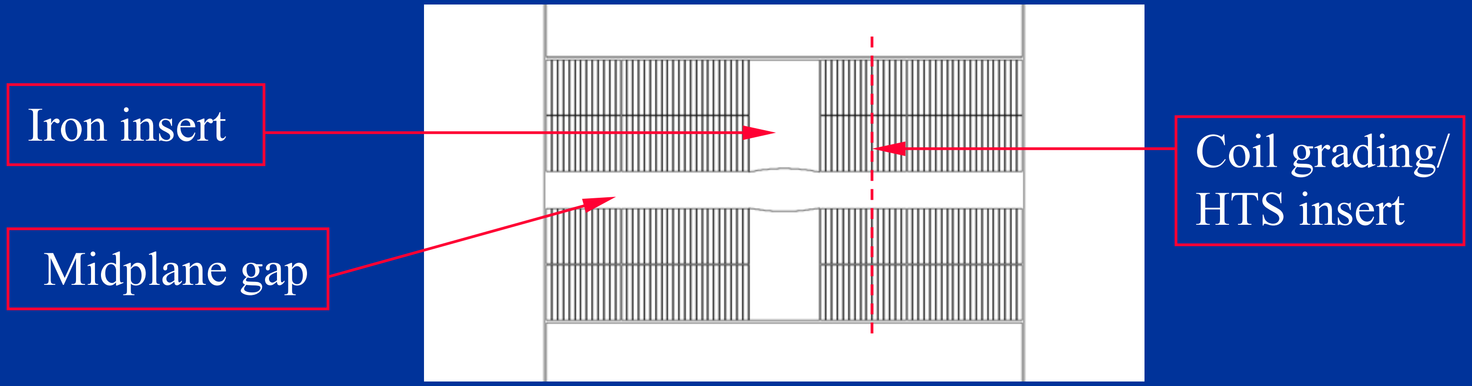
- HD-1a; high stress, high field
  - > 15 Tesla
  - Simplest geometry, no grading
  - Single aperture (less conductor)
  - No conductor at mid-plane
- HD-1b; new fabrication techniques
  - 16 + Tesla
  - Coil grading
- HD-2; limit of Nb_3Sn technology
  - 17 Tesla



Two double-pancake coils with Horizontal orientation

High Field in HD-Series

Design features	Dipole field (T)	Iss (kA)
HD1 reference	16.1	10.7
RD3B conductor	15.3	10.1
Nb_3Sn graded coil 8 turns 1/2 dens	17.5	14.0
HTS insert 7 turns 0.8 mm 361 A @ 18 T	18.6	13.0



R&D Program Tree

5+ Year Plan

RD-3c — RD-3d — RD-4 — RD- — RD-5 - - - →

30kA PS?

SM-1,2,3,4 — SM- — SM- — SM- - - - →

Small Bore
Series/VLHC

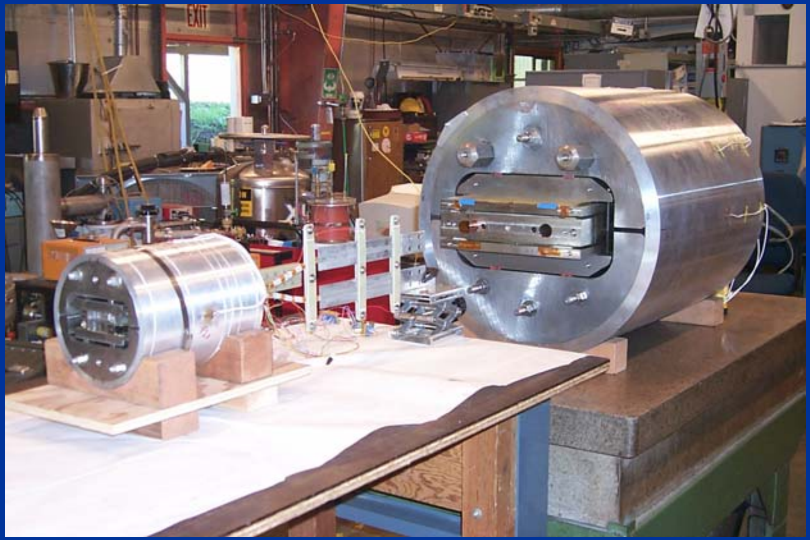
Increase size?

HD-1a — HD-1b — HD-2 - - - →

HTS?

FY02 | FY03 | FY04 | FY05 | ....

Current Status



- HD1 is now under construction
  - Test this summer
- Productive Sub-scale program
  - Evaluation of new cable designs
  - Insulation test for FNAL
  - Quench Protection Studies
- DOE/HEP Conductor Development Program continues to show excellent progress
- Lots of ideas for the future

New Opportunity

- LARP Magnet Program
  - Improve long-term physics research opportunities of the LHC
  - Extend US leadership in high–field accelerator magnets
  - Develop world-wide collaboration on high-performance magnets

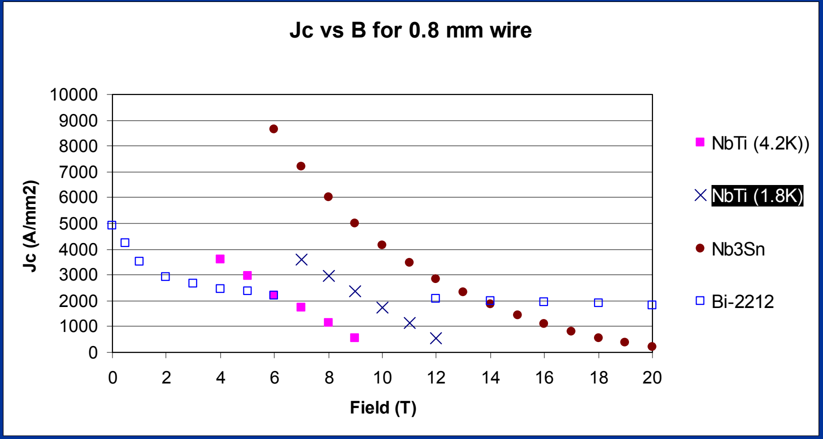
Represents the first opportunity for the use of Nb_3Sn in an accelerator

As world leaders in Nb_3Sn technology for accelerator magnets, we can contribute significantly to this program

US LHC Research Program

- Main Issues
  - High fields and gradients
  - Large beam-induced heat loads
- Program
  - Integrate the three US laboratories and include university participation
  - Leveraged by
    - **Existing technology base**
    - **Intellectual resources**
    - **Facilities**
  - Strengthen international collaboration
    - **Include CERN, ESGARD, EU**
    - **Workshop in Archamps in 1 week**

Nb_3Sn



- 2003 – 05
  - Technology, simple models
- 2006 – 09
  - More complex models
- 2010 – 12
  - Accelerator-ready prototype

LHC Accelerator Upgrades

- Luminosity (IR upgrade)
  - Options
    - **IR I**
      - **Large aperture quad with maximum gradient > 250 T/m**
    - **IR II**
      - **High gradient 2/1 quad with maximum gradient > 300 T/m**
      - **Large bore separation dipole with a field > 15 T**
      - **Smaller bore, 2/1 dipole with a field > 15 T**

Initial program target

- Energy Upgrade
  - Technology development supported by LARP, applied through LBNL base program
    - Small aperture, high field arc dipoles (17 T)

High Field (Nb_3Sn) Dipole Prototypes

9 10 11 12 13 14 15 16 17 T

LHC
(CERN, 1988)

MSUT
(U. Twente 1995)

LHC
Luminosity Upgrade

LHC
Energy Upgrade

RD3c
(LBNL 2002)

RT-1
(LBNL 1999)

D-20
(LBNL 1996)
1.9K

RD3b
(LBNL 2001)

LBNL Superconducting Magnet Program

- Extensive expertise in application of Nb_3Sn to high field magnets
  - Apply proven LBNL technology
    - LHC Upgrades
    - Future HEP Projects
  - Develop and maintain the largest set of HEP options
- DOE has set ambitious goals for the program
  - Supported by a significant funding increase in FY04

In order to maintain our position at the leading edge of this technology, the trend needs to continue